COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

November, 1947

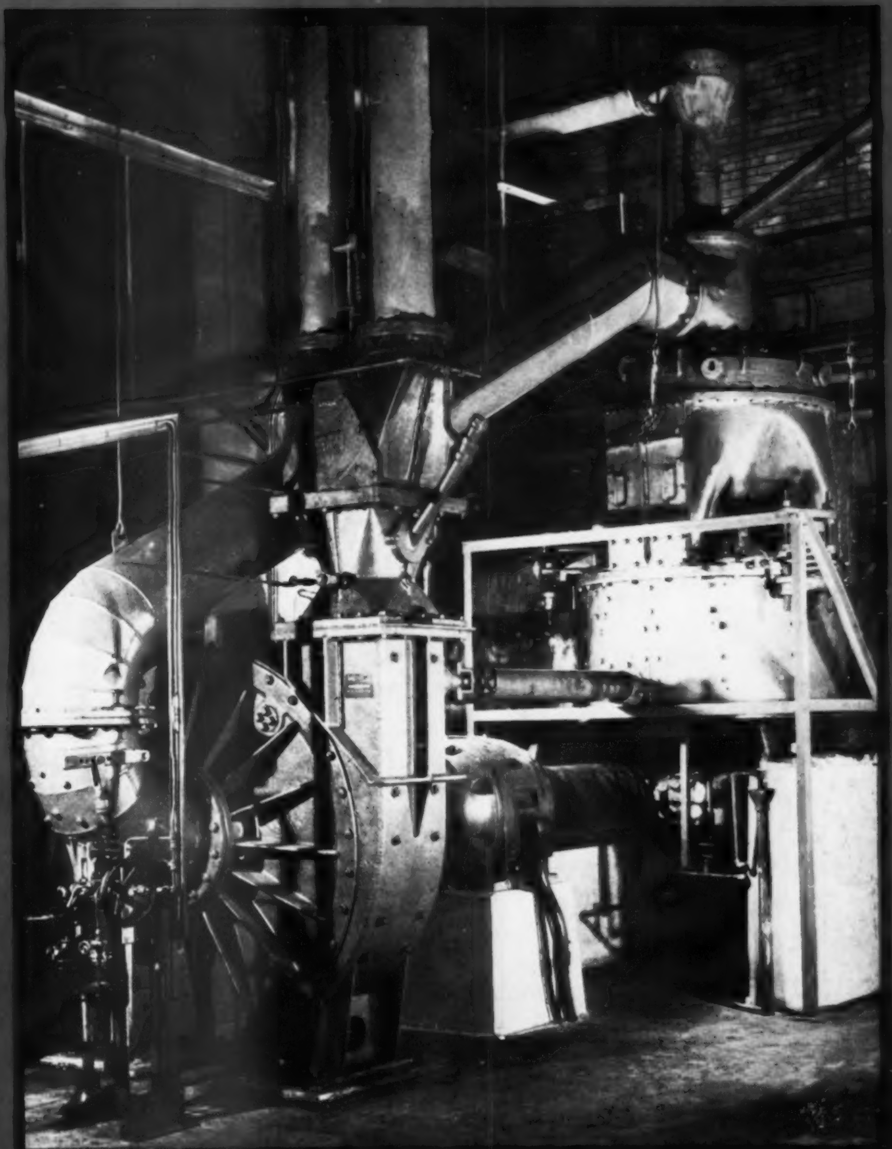

Photo by H. R. Towse

Exhauster side of recent pulverizer installation

Fuels Meeting Stresses Small Plant Problems and Smoke Abatement

Atomic Energy and American Industry

An Appraisal of Gas Turbines for Power Plants

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FEATURE ARTICLES

EDITORIALS

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EDITORIAL

Overlooked Factors in Atmospheric Pollution

Public attention in many cities is now being refocused on smoke abatement. Pittsburgh, for instance, long considered to be one of our smokiest cities, has lately enacted an ordinance calculated to put an end to the emission of objectionable smoke; and agitation in New York City, by civic bodies and by the press, has resulted in the Health Commissioner having appointed an advisory committee, containing engineering representation, to recommend more effective means of smoke control. Many other cities are either considering new laws or are preparing to tighten enforcement of their existing smoke ordinances. This is despite an ever-increasing use of cinder-recovery and fly-ash arresting devices, improved design of fuel-burning equipment, and the educational program on firing methods which was carried out with considerable effectiveness in the later war years by the National Fuel Efficiency Program.

Obviously, the emission of smoke, cinders and fly ash, from whatever source, is highly objectionable and should be curbed to the fullest extent possible. Much still remains to be done toward its elimination, in which the human element seems to present a more difficult problem than the mechanical aspects.

However, scientific studies now reveal that these solid discharges constitute only one—perhaps the lesser—factor in atmospheric pollution. They indicate that, even if smoke and other visible stack discharges were to be eliminated, there would be no assurance that palls would cease to hang over cities. It appears that certain condensation nuclei, some of natural origin and others man-made, are responsible for much of the haze that hangs over cities. These nuclei are hygroscopic and may be of a variety of substances, of which chloride and sulphurous compounds are the more common. They are invisible until condensation forms on their surfaces and a haze or fog is formed. Dust which is ever present in the atmosphere intensifies the condition. Dispersion is largely dependent upon humidity, barometric pressure and air currents, the last mentioned often being dictated by local topography.

An excellent analysis of the nuclei phase of the subject was presented by Professor Neuberger at the recent Fuels Conference in Cincinnati, as reported elsewhere in this issue; and of the effect of air currents, humidity, etc., by H. F. Hebley at the same meeting. Both authors deserve commendation for directing attention to a much overlooked aspect of the atmospheric pollution problem. Not that very much can be done to rectify this situation, because of the many contributing sources of the nuclei; but it is well to know that the visible products of combustion are not the sole offenders.

Electric Utility Growth

The Edison Electric Institute, in its October *Bulletin*, gives some enlightening figures on present activity in the electric utility field, representing a five billion dollar construction program by the private power companies.

Quoting from a recent survey of that industry, it is shown that there is at present an average of only five per cent margin of capacity over anticipated peak demands of this coming winter—a figure considerably below the previously estimated reserves. Fortunately, however, through the foresight of management and the facilities of equipment manufacturers, new capacity is now being added at the rate of 400,000 kw a month, which exceeds the rate of load increase and is calculated to bring up the 1948 reserve to about eight per cent.

It will be recalled that the present estimated total installed capacity in the United States, including utilities, municipal and government plants and private industrial establishments, is around 64 million kilowatts of which private electric utilities account for 41 million. Under the current program, a total of 18 million kilowatts of new capacity will be added during the five-year period ending with 1951, of which over 15 million will be by the private electric power companies. Of the 18 million total $15^1/_2$ million will be steam. Thus by the end of 1951 the private electric utilities will have a capacity of over 56 million kilowatts and the total for the country should be in excess of 82 million kilowatts.

About 75 per cent of the new capacity is for extensions to existing plants which means that new steam central stations will account for nearly four million kilowatts. Moreover, the trend toward large units is indicated by the fact that of 264 turbine-generators, representing $11^3/_4$ million kilowatts, 66 units exceed 60,000 kilowatts and 23 are over 90,000 kilowatts.

It is significant of the growth in both industrial and residential demand that the annual output of electricity by utilities has doubled since 1937, the annual average residential use alone having increased from 800 to 1400 kilowatt-hours. All indications point to a further steady increase over the next few years.

The foregoing figures will be confounding to those who predicted a large post-war drop in energy demand, and gratifying to those in the utility field whose foresighted planning places them so far along in their preparation for the electrical needs of the years ahead.

Fuels Meeting Stresses Small Plant Problems and Atmospheric Pollution

THE Tenth Annual Joint Fuels Conference of the A.S.M.E. Fuels Division and the A.I.M.E. Coal Division occupied two days at the Hotel Gibson, Cincinnati, on October 20 and 21. Following the usual practice, the program was divided between sessions dealing with coal production and those pertaining to coal utilization. Only the latter are here reported.

Small Boiler Plant Problems

The design and operation of small coal-fired boiler plants were discussed from several angles by a panel consisting of **C. A. Reed,** of the National Coal Association, who dealt with "The Relation of Fuel to Proper Equipment Operation"; **P. F. White** and **C. F. Golding,** of Anthracite Institute, who discussed "Application of Anthracite Stokers"; **H. L. Wagner,** of Detroit Stoker Company, whose topic was "Application of Bituminous Stokers"; **H. N. Hermann,** consulting engineer, who spoke on "Design of Plants from a Consulting Engineer's Viewpoint"; **W. H. Pugsley,** of Hays Corporation, who reviewed "Instruments and Combustion Control for Small Plants"; **C. E. Miller,** Utilities Branch of the U. S. Engineers Office, whose subject was "Economics of Boiler Room Operation"; **H. B. Lammers,** Director of Engineering of the Coal Producers Committee for Smoke Abatement, who discussed "The Effect of Proper Application of Combustion Equipment in Smoke Elimination"; and finally **J. F. Barkley,** Chief of the Fuels Utilization Branch of the U. S. Bureau of Mines, who told of "Experiences with Government-Operated Plants."

Mr. Reed credited the wartime engineering assistance rendered by the National Fuel Efficiency Program with having brought about considerable improvement in small plant operation, and also considered that equipment manufacturers had gained considerable experience from the conditions that then had to be met. However, he was of the opinion that the purchaser of small heating or power equipment too often buys competitively on a price basis. Herein lies an opportunity, on the part of equipment sales and fuel people, for education on the real merits of purchasing properly such as will effect savings over the years through higher efficiency, lower maintenance and possession of equipment capable of using a wider range of fuel. It is well known that if a plant installs the cheapest equipment or that which demands close tolerance of fuel burned, it will often have repeated outages and high maintenance. Consumers in the class ranging from 2000 to 10,000 tons of coal per year are the largest fuel wasters and usually experience the highest maintenance costs per ton of fuel burned.

In conclusion, Mr. Reed pointed out that every industry is up against a typical war aftermath; that world conditions make it necessary that the United States export large quantities of coal; and that fuel stocks are greatly depleted at certain plants; which conditions make it more necessary than ever before that plants be able to burn successfully coals within a wider range of specifications and still obtain high capacity and good efficiency.

Anthracite Stokers

Messrs. Golding and **White** called attention to the Brunner Anti-Stream Pollution Act in Pennsylvania as having forced the Anthracite Institute to engage in a research program to pelletize silt taken from the breaker wash water. These pellets are now under trial at various colliery boiler plants with a view towacd releasing more buckwheat Nos. 2, 3 and 4 which now are standard colliery fuel. The importance of this is shown by the fact that colliery fuel amounts to 3.78 per cent of the total anthracite production. Dredged river coal at present amounts to 2.16 per cent.

There are now 880 installations, generating a total of over fourteen million pounds of steam per hour which consume annually over five million tons of rice and barley. Some 10,700,000 tons of barley and smaller sizes were produced in 1946 which accounted for about 90 per cent of the steam produced by anthracite. The shift toward consumption of the smaller sizes continues, but there are no apparent grounds to fear a future inadequate supply of the smaller sizes.

The authors then reviewed the four classifications of stokers available for industrial or semi-industrial applications with small-sized anthracite. These are underfeed stokers, subdivided into the stationary and the moving-bar types, chain-grate stokers, spreader stokers, and traveling-grate stokers.

The moving grate-bar type of underfeed stoker is considered preferable because the keys keep the fuel bed moving and self-cleaning. However, many stationary-grate machines are giving satisfactory service. Anthracite is at its best if left undisturbed from slicing or poking operations. Burning rates with the moving grate-bar type range from 20 to 25 lb per hr per sq ft of grate and efficiencies of 73 to 75 per cent are obtainable with some designs. A floating type of control is preferred to the start-and-stop type.

Several manufacturers of chain-grate stokers are showing interest in attacking the anthracite market which they have heretofore neglected. Burning rates listed are up to 40 lb per sq ft per hr with buckwheat No. 1; 30 to 35 lb with rice; 22 to 25 lb with barley; and 20 to 22 lb with buckwheat No. 4. For the last-

mentioned size the recommended air space in the grate bar is 8 to 10 per cent. Guaranteed efficiencies are usually around 70 per cent.

With spreader stokers the firing of 100 per cent anthracite has not yet proved successful, but admixtures with 25 to 50 per cent bituminous coal have been burned without difficulty on this type of stoker.

The recommended fuel for use with traveling-grate stokers is usually buckwheat No. 3 or No. 4. Fuel beds average 2 to $2^1/_2$ in. thick; grate speeds up to 110 ft per hr are employed; and burning rates of 15 to 26 lb per sq ft per hr are general with up to 30 lb on peak demands. The usual efficiencies range from 72 to 75 per cent with barley and 69 to 72 per cent with buckwheat No. 4.

Bituminous Stokers

In discussing the application of bituminous stokers to generating capacities of 3000 to 20,000 lb of steam per hr, corresponding to coal consumptions of 1000 to 8000 tons per year, **Mr. Wagner** listed the single-retort underfeed and the spreader. For the former it is advisable to select coals of the free-burning type with relatively high ash-fusion temperature. A good eastern coal requires a somewhat higher ash-fusion temperature than a midwestern coal. While the better coals are preferable for this type of stoker, the washing and cleaning processes now commonly employed at the mines for the lower grade fuels have made them more suitable than formerly for the single-retort underfeed.

Burning rates of 30 lb per hr per sq ft of projected grate area are reasonable when burning the better grades of coal, but for many midwestern coals this should be reduced to 25 lb or even 20 lb per sq ft per hr. These rates may be increased 20 to 30 per cent for short peak periods. Furnace heat releases of 50,000 to 60,000 Btu per cu ft per hr can be maintained without smoke, although it is advisable to design for 45,000 to 50,000 Btu for continuous rating.

As to the spreader type stoker, Mr. Wagner stated that the stationary grate type is usually limited to a grate length of about 9 ft, above which cleaning becomes laborious, but dump grates can be built up to 15 ft in length. This latter type is more flexible and is recommended where basement facilities permit. For larger installations the continuous-ash-discharge type offers many advantages.

Burning rates of 35 to 40 lb per sq ft per hr are reasonable for continuous operation and 40 to 45 lb for 2- to 4-hr peaks. Since much of the coal is burned in suspension, adequate furnace volume is essential. A heat release of 35,000 Btu per cu ft per hr can be successfully maintained, although in cases where the heat absorption area covers less than 25 per cent of the furnace wall area, it is advisable to design for a maximum heat release of around 40,000 Btu per cu ft per hr. These figures are averages and will vary with the shape of furnace, length of flame travel and location of the water-cooled surface.

The amount of fly ash carried out of the furnace by the gas stream can be reduced materially by providing overfire air to create turbulence and to return the fly ash from the soot hoppers back to the furnace. A cinder-return system is an integral part of the spreader stoker and should not be regarded as an accessory that can be omitted. An adequate combustion control is also essential.

With the continuous-discharge type grate speed is determined by the amount of fly ash in the coal to maintain an ash depth of about 4 in. where it spills into the ash pit. Furthermore, since there is only about a two-minute fuel supply in the furnace at any time, widely fluctuating loads can be carried. A heat release of 650,000 Btu per sq ft of grate per hr is reasonable and can be increased for peaks. Low-volatile highly coking eastern coal burns as readily on this type of stoker as high-volatile midwestern coal.

Plant Design Factors

In considering the design of plants from the consulting engineer's viewpoint, **Mr. Hermann** listed as important factors: (1) service, character of load and standby capacity; (2) location of plant and its influence on design; (3) type of operating personnel; (4) external influences, such as codes and local ordinances; (5) equipment; and (6) fuel supply.

In the smaller industrial plants utilizing steam for process and where operations are carried on over a 24-hr period, he considered 100 per cent standby facilities generally justified; however, in larger plants having three boilers, any two of which can carry the maximum load, only one-third the installed capacity represents standby and this arrangement frequently results in the lowest initial cost. But where there are little or no process demands and where the operating period is limited to 8 to 12 hr a day, with week-end shutdowns, the omission of standby capacity may be justified in some cases.

Experience and skill of the plant operators, as well as the overall supervision, or its lack, must be taken into consideration when designing a plant, especially the smaller ones. Operation of these plants is often entrusted to licensed firemen and management does not realize that the small difference between this man's salary and that of a competent engineer represents only a nominal increase in yearly operating cost which is more than offset by savings in operation. Moreover, a substantial investment in boiler plant equipment is at stake.

In selecting boiler plant equipment considerable importance attaches to choosing that made by manufacturers who maintain reasonably adequate service facilities and from whom emergency repair parts can be promptly obtained.

Unfortunately, the fuel often has to be selected on the basis of its availability for the equipment with which it is to be used. Because of this, much trouble has been experienced in burning coal having high ash and high sulphur content and low Btu and low ash-fusion temperature in furnaces not designed for such coal. Therefore, in designing a new installation the furnace and coal-burning equipment should be selected to handle the poorest grade of coal that it may be necessary to burn. Furthermore, with ever-increasing cost of fuel, it becomes increasingly desirable to provide adequate combustion control. Except where first-rate supervision is maintained in the smaller plants, Mr. Hermann did not recommend CO_2 recorders.

Instruments and Combustion Control

In discussing instruments and combustion control for smaller plants ranging from 3000 to 20,000 lb of steam

per hr, **Mr. Pugsley** listed draft gages, steam-flow meters, feedwater meters, instruments that serve as combustion guides, and simple automatic combustion controls.

For such a plant a three-pointer draft gage should prove ample. Indication of the furnace draft is the most important; next is that of the air entering the furnace for combustion; and third the draft ahead of the boiler outlet damper.

The speaker considered it good engineering practice to provide each steam generator with a steam-flow meter so that a check on the operating efficiency of each unit can be had as well as information on its output. However, depending upon piping arrangement and operating conditions, it may be possible to use one steam-flow meter, connected to the main steam header.

Feedwater flow meters have, to a large extent, given way to steam-flow meters in the smaller plants where a choice must be made between them. In larger industrial and utility plants both are employed.

Combustion guides include an orsat for manual analysis of the flue gases, the automatic CO_2 recorder, and the air flow-steam flow relationship. The orsat is primarily a test instrument for checking the calibration of the automatic CO_2 recorder, or checking air flow-steam flow relationship on boiler efficiency. The automatic CO_2 recorder is used extensively in this size of plant and its readings are used as a direct guide by the fireman in adjusting the fuel-air ratios for combustion efficiency. It is good practice to equip each steam generator with a separate CO_2 instrument. Use of the relationship between air flow and steam flow can be obtained by combining an air-flow record with that of steam flow on the chart of the steam-flow meter.

In addition to the above-mentioned, it is preferable to provide recording instruments for steam pressure in the main header, for temperature and pressure of the feedwater and for temperature of the flue gases at the outlet of each steam generator.

Mr. Pugsley then described the positioning and metering systems of combustion control. While each responds to changes in steam pressure, controls the rate of fuel and air supply and employs a furnace-draft controller, the two systems differ in the method used to control the rate of fuel feed and air supply. Despite certain limitations and sources of error, the positioning type will do a good job of controlling steam pressure and furnace draft; but a better answer to the control problem is the metering system which compensates for most of the variables and can be easily and accurately calibrated to a high degree of efficiency.

Economics of Boiler Room Operation

The current widespread conversion of small boiler plants from coal to oil or gas **Mr. Miller** attributed largely to a desire to effect savings in operating labor costs; for with the price of both coal and oil advancing, relative fuel costs are no longer a factor. The smaller coal-fired boiler plants are generally deficient in automatic equipment as they are usually incidental to the plant as a whole whether it be a hotel, hospital, apartment or small industrial, and therefore are not labor saving. This situation, he believed, could be obviated by better planning and providing the small boiler plant with more automatic equipment.

Application of Combustion Factors in Smoke Elimination

During the past eighteen months **Mr. Lammers'** committee made engineering surveys in thirteen large cities, as well as many smaller ones, to determine the sources of smoke and air pollution. The data gathered during these surveys showed conclusively that undue emphasis has been placed upon mechanism alone without proper follow-up as a solution. In all too many plants the personal equation was found to have been overlooked, although as important as equipment and controls. Carelessness and indifference are the chief allies of poor efficiency and smoke emission, and until these deficiencies in plant operation are corrected, solution of the air-pollution problem will be difficult.

Government-Operated Plants

Mr. Barkley, whose duties entail supervision over numerous government-operated fuel-burning plants, was of the opinion that many of the shortcomings of small plants could be traced to the designer's lack of experience in actually operating a boiler plant.

Capabilities and experience of small plant operators vary considerably, and it cannot always be expected that expert operators will be available. However logical from a designer's standpoint a plant may be on paper, if it has not been designed to fit the type of operator who will run it, the design is poor.

Discussing factors that make for low-cost operation and freedom from trouble in the small plant, Mr. Barkley favored a straight-tube boiler over the bent-tube type of water-tube boiler because of the greater ease of internal inspection, cleaning and replacement. Stokers should be able to handle a wide range of coals, in which connection the spreader type has marked advantages. As to controls, he cautioned that these should be simple, covering furnace draft, air supply and coal feed. While he advanced no arguments against the use of steam-flow meters, steam flow-air flow meters and CO_2 recorders, he considered them useless unless maintained in reasonably good operating condition. Since few small plant operators are instrument minded, the solution may be in provision of instrument service by the manufacturers for a small annual charge. Furthermore, since the operators are not schooled in chemistry, outside help is always desirable to insure proper feedwater conditioning.

Atmospheric Pollution

The "Significance of Condensation Nuclei in Atmospheric Pollution" was discussed in a paper by Prof. **Hans Neuberger** of Pennsylvania State College, who reviewed the two types of aerosol, namely, dust and condensation nuclei, and stressed the predominance of *natural* in contrast to *man-made* sources of atmospheric pollution.

"In our everyday life," he said, "visual perception plays perhaps a more important role than any of the other senses. It is, therefore, quite understandable that the average person associates with the term *atmospheric pollution* clouds of dust, palls of smoke or deposits of soot; but the more important aspects of pollution generally escape attention."

In general, it can be stated that the atmosphere

would contain dust even in the absence of sources occasioned by human activity, because among the chief natural sources are volcanic eruptions, forest fires and sand or dust storms from desert or other dry areas from which dust may be deposited many hundred miles away. For example, a single dust-fall in March 1901 carried an estimated two million tons of dust from the African desert to various parts of Europe, and in February 1903 ten million tons of red dust from northwest Africa were deposited over England. Man-made sources include industrial furnaces and processes of various kinds, chimney discharges, locomotives (both diesel and steam), steamships, automobiles and various domestic sources.

The second type of suspension which is far more important than neutral dust is that made up of hygroscopic substances having an affinity for water. These play an important role in the transformation of water vapor into liquid water or ice particles. In the free atmosphere these hygroscopic suspensions furnish the surfaces necessary for the process of condensation and are therefore called *condensation nuclei.*

There are a great variety of substances which serve as such nuclei. These include chloride salts and sulphuric acid, as well as phosphorus compounds, oxides of nitrogen, nitrous acid, etc. Sulphur dioxide under the influence of ultra-violet radiation is oxidized to the highly hygroscopic sulphur trioxide which, together with water vapor attracted from the air, forms minute droplets of sulphuric acid. This explains the frequently observable fact that in industrial areas a thin haze or smoke layer will often turn into a dense fog when the morning sun shines upon it.

Winds from the land apparently carry substances, such as sulphur dioxide from combustion processes, and these become nucleogenic under the influence of sunlight; whereas the nuclei in winds from the sea consist chiefly of chlorides or other salts which are hygroscopic without chemical transformation due to sunlight. In fact, salt nuclei have been found in the middle of continents, thus illustrating the ease with which these small suspensions ride the air currents.

But as in the case of dust, man-made sources are insignificant compared with natural sources.

Probably the most obvious physicochemical effect of the aerosol is the corrosion of exposed surfaces, caused by the chlorine, sulphur and ammonia compounds of which the nuclei consist. Very little factual data are available as to the effects on the human respiratory system.

Influence of Air Movement

In the second paper on this general subject, **Henry F. Hebley,** Director of Research of the Pittsburgh Coal Company, dealt with "Stability of the Atmosphere and Its Influence on Air Pollution."

Basing his study largely around conditions in the Pittsburgh area, he cited a commonly observed phenomenon where of two days, one in winter and the other in summer, with industrial activity comparable but considerable additional stack discharge from space heating in winter, the atmosphere would be clear and bracing on the winter day and murky on the summer day. Again this situation might be reversed. To account for this he reviewed the topography of the Pittsburgh area and showed the influence of wind and air motion which was also discussed in general, as well as the effect of temperature and altitude.*

Underground Coal Gasification

At the banquet on Monday evening, **W. C. Schroeder,** of the U. S. Bureau of Mines, and **H. Fies,** of the Alabama Power Company, told of the recent tests on underground gasification of coal at that company's mine at Gorgas, Ala.

The speakers explained that the experiment was undertaken with a view to ascertaining possible advantages over conventional mining methods in elimination of human underground work, lower cost in utilizing the energy from coal, and elimination of handling millions of tons of coal and ashes; also any disadvantages and troubles that such a method might incur.

This particular section of the seam was isolated and the fire was started with oil which, in turn, was ignited by an incendiary bomb. Air was introduced under 8 in. of water pressure at the start, but as resistance built up this had to be gradually increased up to 40 in. A maximum temperature of 2200 F was measured and during the six-day period when air alone was introduced the average heating value of the gas was 70 Btu per cu ft. When a mixture of oxygen, air and steam was substituted, the Btu value was increased to 110; and a mixture of 65 per cent oxygen and 35 per cent steam gave an average of 134 Btu, although individual samples on several runs with steam alone ran as high as 319 Btu per cu ft.

The coal appeared to burn completely and the heat from combustion caused the roof to fall, slag and swell so as to fill the space occupied by the coal. However, there was no caving in at the surface despite the cover being only 30 to 40 ft.

Conclusions by the speakers were as follows:

1. Combustion can be maintained without difficulty, and in a passage of about 300 ft or considerably less practically all oxygen is consumed. This indicates turbulence in the gas stream which brings all parts of it into contact with combustible material.
2. Coking precedes actual combustion and produces a coke bed that should be very satisfactory for producer- or water-gas operation providing the oxygen and steam can be forced through this bed.
3. This experiment shows that coal can be burned and gasified completely underground with little or no loss of combustible material.
4. In this experiment, it is doubtful if high enough temperatures or a sufficient area of high temperatures were obtained to secure gas of maximum heat content.
5. The roof will fall (in this case) following combustion of the coke. This does not stop the flow of air or combustion but it does increase the back pressure on the blower.
6. With this experience as a basis, it is planned to make further tests at Gorgas.

At the Monday luncheon **Otto de Lorenzi** showed kodachrome motion pictures of the operation of a continuous discharge spreader stoker and commented on the various phenomena observed.

* For a discussion of some of these factors, see Mr. Hebley's paper on "Factors Rarely Considered in Smoke Abatement," COMBUSTION, March 1947, pp. 43-48.

ATOMIC ENERGY and AMERICAN INDUSTRY

In a talk before The Economic Club of Detroit on October 6, Mr. Lilienthal reviewed the policy of the Atomic Energy Commission which, despite the present need for secrecy, aims at ultimate dependence on American industry to evolve many useful applications. The need for further extensive research is great and there is no basis for assuming that commercially economic atomic power plants are "just around the corner," although this may be possible on a laboratory scale within the next twelve to twenty-four months. After enumerating some of the problems yet to be solved, Mr. Lilienthal concludes that at least eight to ten years will lapse before a useful and practical demonstration plant is in operation.

By DAVID E. LILIENTHAL

Chairman, U. S. Atomic Energy Commission

WHAT are the prospects for electric power from atomic energy? When can we expect a substantial part of this country's energy requirements to come from atomic energy plants? Are such things right around the corner? Can power and heat from atomic energy solve the coal troubles of Britian and France, the Ruhr and Belgium and Austria, and help put Europe back on a self-supporting basis in the next few years? Should the power industry slow up its plans for expansion of steam-generated power? Should Congress drop the St. Lawrence power project and call a halt on California's Central Valley, and on other irrigation projects in which water power is a major factor? Should insurance companies and other investors in the power industry begin to worry about the effect of atomic energy on their holdings?

Such questions as these could be extended into a considerable list. They are important.

The course of American industry and indeed the whole of American economic life is involved in the answers. Therefore, the people of this country are entitled to candid, straightforward answers based upon the best available information and judgment. The only important limitation on that fundamental right is the sensible rule that where, on balance, the national security would be adversely affected, information regarding atomic energy must be kept secret from the public. The public ought to scotch any tendency in officials, either civil or military, executive or legislative, to set up secrecy and security as a device to protect them from public criticism and to cover their mistakes.

Atomic Power Not Around the Corner

Let me say at the outset that in our opinion the long-time prospects of atomic power are bright indeed. America's leadership in atomic energy research and production is one of our nation's great assets.

But the fact should be faced squarely that the first commercially practical atomic power plant is *not* just around the corner. Before such a plant will be possible we must first cut through a jungle of difficult scientific and engineering problems. And even after these have been cleared away, and a commercially useful plant of some size is in successful operation, there are other barriers that must be overcome before any substantial part of our energy supply comes from atomic energy

This does not mean that within the next twelve to twenty-four months useful electric power could not be actually developed from a nuclear reactor. Such atomic power could turn motors and light bulbs, and heat buildings. As a matter of fact, on a demonstration basis (a thousand kilowatts or so) that could certainly be done; but what is definitely *not* near at hand are large-scale, practical commercial applications of power from atomic energy.

The economics of power production from nuclear reactors cannot be divorced from the scientific and engineering problems. But this is not economics as we usually use the term, which is a comparative analysis of the costs of producing power from one type of fuel as opposed to another. There is as yet no firm basis for estimating competitive cost position of useful power from nuclear sources with respect to the cost of generating power from conventional fuels.

The following story is being spread in foreign nations by those unfriendly to American democracy, as well as by others who are friendly but uninformed:

"Here we are facing another winter. Lack of coal will close industry in England, France, Germany, Austria, perhaps Belgium. People will be cold, will freeze, be out of work. The United States could have prevented this; she could prevent it happening again. For the United States has the secret of atomic energy, and in that secret is the answer to limitless, almost costless energy and heat. Only America's military imperialistic passion stands in the way of solving Europe's most crying need, a new source of energy and heat."

This story is completely without foundation in fact.

Broader Aspects of Nuclear Energy

The subject is obviously far broader than the prospects for atomic power. It embraces issues concerned with the military use of atomic energy, such as current proposals for decentralization of cities and location of industry underground. It includes the whole field of industrial and business opportunities in this field,which in turn, include the possibility of manufacture and sale by private industry of molecular compounds containing radioactive and stable isotopes, among them carbon, substances now produced in some quantities at Oak Ridge. It involves the possibilities of the use of such radioactive tracers in industrial chemical process control and research problems, and in oil-well surveys throughout the petroleum industry, as well as in hydrocarbon cracking processes for research and control. The subject includes the steps the Commission has already taken, and others it will shortly take, to insure industrial and engineering participation, from the very beginning, in the design of power reactors. It embraces the whole attractive outlook in the use of reactors producing beams of very high neutron intensity for the treatment of many kinds of materials, among them metals. This may open a new era in metals for industry. It also involves the training of engineers and industrial men in these new fields, so that American industry can keep abreast of developments as they occur, and in this way help protect against any tendency toward inertia and complacency that the existence of the present Government monopoly may bring with it; for this inertia is an always present danger with most monopolies, whether they be governmental or private.

There is a very real difficulty in achieving the active widespread participation of American industry and engineering in atomic energy development which is so essential. That difficulty is the continued need for secrecy in important sectors of this work. There is every reason why this fact should be candidly recognized at this time.

Now secrecy and industrial progress are not cut out of the same cloth. Government-imposed restrictions upon access to information about atomic energy development are not calculated to invite and encourage a ferment of ideas, self-criticism, competition, and cross-fertilization between skills that has given America its industrial strength and vigor.

The necessity for secrecy at vital points at this stage in world affairs is certainly clear. Nor has anyone ever proposed that at this time the atomic energy project could be turned over to private competitive production and relieved completely of security limitations. There seems now to be no alternative to the present course.

The Commission certainly believes that this atomic industry can never flourish and grow and find its proper place among the elements of our national strength unless it sends its roots deep and wide into the same soil that has nourished the automotive and other industrial giants, the soil of competitive private industry.

The business of making atomic power happens, unfortunately, to be the same as that of making atomic bombs, up to a point very far along in the process. The Congress last year had no choice, wishing as it did to maintain government control of atomic weapons, except to give both the weapon development and the possible power development over to the care of a government agency. It was apparent that where one went, the other had to go.

Non-Government Agencies Now Carrying on Assigned Research

But the Atomic Energy Commission does have some room for choice in deciding whether the work toward an atomic energy industry shall be carried on chiefly by the Government directly, or chiefly by American industry as agents and contractors of the Government. The Commission has pursued the latter course, as to all those parts of the work that are not predominately weaponeering. We realize fully that if the nation is ever to have an atomic power industry that industry must, like our other great industries, be the product of the talents and efforts of a wide sector of the people. We do not forget that the mammoth developments inherited from the Manhattan District were built, improved and operated by American industry, under governmental direction. With these monuments of achievement before us, we are not likely to underestimate the role which industry can play, and must play, in the development of this field toward peaceful ends. Our practice today is and is likely to continue to be to distribute the task, once we have broken it up into bits which can be purged of too serious hazard to security; to distribute it out to industry and to educational institutions spread widely over the nation wherever the required talents and facilities and interest can be found. We want this enterprise to enlist a widening area of our economy, so that progress will be made rapidly and effectively, and so that an atomic industry, when it is left to grow by itself, will not find it has been planted in shallow soil. Correspondingly, we want to keep the governmental machinery for managing and directing this enterprise as small as possible.

End Products Small

The production of fissionable materials is today a huge industry possessing great complexity and diversity. It represents an expenditure to date in the neighborhood of $2^1/_2$ billion dollars. The materials that enter this operation in truck loads come out, as an end product, in teaspoonfulls. The end products are two. One is a form of uranium known as U235 and the other is plutonium, a new man-made element. Both of these products are used for atomic weapons, as well as for research reactors, and will be used in power reactors when such have been designed and built.

Whether atomic energy is used for peaceful purposes such as the production of power or for weapons, the same steps and processes and industrial activities are required up to the point where at Los Alamos an actual weapon is put together. The atomic industry of the future we may hope will be confined only to peaceful uses. It has been the purpose and course of this country to seek workable, effective, international arrangements that would insure that result and in the name of common humanity to be content with nothing less.

Now let us consider the status of the development of atomic energy for power. When the story of the atomic bomb was first told to the world there was great optimism that a new source of energy was virtually in our grasp. It is easy to see why there was this optimism. For here we were drawing upon a source of energy quite

different from any known before. Let me illustrate. A lump of coal about the size of a softball, if burned would produce a negligible amount of energy; but a cylinder of uranium, approximately the size of the lump of coal, after the fission process is complete, is equivalent to more than 2500 tons of coal. Atom for atom the energy secured from the *burning* of the coal and from the *fission* of the fissionable uranium has a ratio of *one to sixty million*. No wonder there was initial optimism.

But to get the energy out of uranium or plutonium—as in a bomb—and to use the uranium or plutonium in a controlled reactor as a source of heat for electricity or otherwise—between these there is a whole mass of involved, difficult, scientific, technical and industrial engineering problems. These facts compel the conclusion that power from atomic energy is definitely not just around the corner.

Problems to Be Solved with Reference to Power

First, consider just what it is that has to be done before we can have an atomic power industry. On the surface it does not seem to be too complicated a task. Atomic nuclei have energy stored in them. In the case of uranium 235 and plutonium we know how to get this energy out, by means of a so-called nuclear chain-reaction. Uranium and plutonium exist or can be made. We know how to start a reaction and how to keep it going at a constant controllable rate. The problem that remains is to convert this energy into a form suitable to provide energy to, say, a turbine, safely and efficiently. It sounds like a simple job but in reality, as we see it now, it is one involving very considerable difficulties.

There are at least four elements to the problem of making atomic power a practical reality. One is to get energy in a usable form, which probably means in the form of high-temperature heat. Second, is to have a reasonable rate of generation of power per unit of nuclear fuel invested. By nuclear fuel I mean, of course, some form of uranium and plutonium. Third, is to have adequate stocks of such fuel to activate a sizable atomic power industry. Fourth, is to prevent wastage or loss of this precious fuel in the complex business of handling it.

To state all of the difficulties in any detail is not now possible, for the obvious reason that some of them lie close to those of providing the materials of atomic weapons. What I can do is therefore limited to mentioning a few important and typical examples of the technical problems now faced.

Low-temperature energy not directly used for power production is now generated at Hanford, the plutonium factory, from natural uranium metal. But the Hanford reactors were built for the prime purpose of manufacturing plutonium. The energy they yield in the form of heat is merely a nuisance. It is sent down the drain into the Columbia River. Therefore, when useful power and not plutonium is the prime objective, we face a host of problems for which the Hanford experience offers no practical answers.

Aside from the fissionable materials—uranium 235 and plutonium—which may be the energy sources in a reactor, the reactor itself calls for materials of construction.

These materials must be carefully chosen, with particular attention to their nuclear properties. Their ability to absorb neutrons is most critical, for if there is too much absorption of neutrons by these supporting materials the nuclear chain reaction suffers. Most materials which would be considered from an engineering standpoint for the structural materials in a power reactor, absorb neutrons far too readily to be acceptable from the nuclear viewpoint. They would stop the chain reaction. Before we can go forward with an atomic power industry the properties of the few possible materials must be known—their metallurgy, strength, corrosive properties and the like—all under the conditions of the fantastically intense radiation which exist in a reactor. These properties of materials must be studied and understood in the same sense that the properties of steel have been studied and understood for the uses to which steel is put.

If atomic energy released in the form of heat is to be converted to industrial energy with any reasonable efficiency, the source of heat—the nuclear reactor—has to run at a reasonably high temperature. This is an inescapable fact of science and engineering. This means that all our materials must be chosen and designed to endure the stresses that go with such temperatures. For the special and rather little known materials which seem likely to be adapted to such a reactor, the mechanical and thermal properties are not known. This knowledge we must have before real headway will be made.

At Hanford the heat of the reactor is extracted by water which flows over the "canned" uranium, through a multitude of narrow passages. At the temperature required in a power reactor, water or steam is not a good coolant. Instead a liquid metal coolant may be used—one whose nuclear properties will stand the test. No one knows much yet of the general properties of such coolants, and this ignorance must be replaced by firm knowledge.

Hazards of Nuclear Power

The ordinary power plant offers few hazards to health and safety, but the vicinity of a nuclear reactor is a different story. As the reaction proceeds, and for a long time after it has been stopped, the reactor is a source of various radiations which are lethal. Great care must be taken not only to povide shielding, but also to provide faultless control of the reactor. These controls have to be capable of rapid changes and therefore must be quick-acting throttles.

When fission takes place energy is released. Additional neutrons are given off in the fission process. These neutrons produce fission in other nuclei. This is the familiar chain reaction. But something is left behind, the result of the splitting of the nucleus. This mixture of the isotopes of many elements is very radioactive. Inside the reactor, where all this takes place, the effect of these "hot" elements on the operation of the reactor is bad. Some of the new elements absorb neutrons readily, so that their effect is to quench the nuclear reaction. The fission products—the nuclear ashes—must be removed and the remaining nuclear fuel recovered to be used again. This is a chemical separation job that presents some highly complex and difficult problems of chemistry, chemical engineering and metallurgy. Moreover, it must be carried out by remote control to protect the workers from the lethal radiations.

Until these many problems have been worked over hard, we do not have a good basis for the engineering design of an atomic power plant. In Commission laboratories over the country, and in industrial laboratories

and institutions, these problems are being studied. The ultimate objective is a reactor to operate at a rather high temperature. From such a reactor useful power will be extracted, but this reactor will in all probability use an expensive form of nuclear fuel—plutonium or the rare enriched uranium, U235. For all but very special uses, this fact puts a high premium on efficient processes for separating the radioactive poisonous fission ashes from the unused nuclear material. And these have yet to be developed, although the work is now under way.

The foregoing is a partial list of the technical problems which must be solved before atomic energy for peaceful purposes will be available to the United States. The problems dictate the kind of research and development program that has to be undertaken. They also dictate largely the places where this research and development can be done and the people who must do it. Much of the work at the moment is not engineering work, because the fundamental scientific information on which the engineering could be based simply does not exist. The investigations which must be made are, generally speaking, those that the scientist, and not the engineer, is by nature and training skilled to undertake. The devices and equipment which must be used for these studies are in most cases the laboratory equipment of the scientist. This means that we have had to look largely to the universities for help with this early phase of the program. As the research shows the way into development and the development leads finally to the application, the Commission will, of course, turn at each phase to the group or groups best equipped to solve the problems then before us. The work as we see it now will lose its predominantly scientific tinge and will become the work which American engineering and industry can do well and should do.

The final question is that of a time estimate. Just when will the first atomic power plants begin to appear? How fast can the industry grow?

Answers to such questions as these cannot be precise, but I can say with complete sincerity that I do not believe anybody's estimate is more than an educated guess. All our technical advice is that we can be confident of success—success with the technical problem—but the date has to be shifted back and forth with every report of disappointment, or of "pay dirt," from the laboratories. This much one can count on: If we do not go at it with vigor and a sense of urgency, if we go to sleep on the job, it will take a hundred years.

As our staff, advisers and contractors see it now, it will be a long hard grind. The most common estimate or guess is from eight to ten years to overcome the technical difficulties and have a useful practical demonstration plant in operation.

Even those who are willing to make this guess of ten years are for the most part unwilling to couple with it an estimate of the economic costs, or even the total amount of atomic power likely to be available in that time.

Shortcuts will be found, of course, and clever inventions and discoveries will be made, with respect to each of the technical problems enumerated. However, we do not now see any reason for hoping that a major shortcut around the whole mass of technical problems, or the other limitations not here discussed, can be found. It looks as if the job will have to be done the hard way. This means it has to be done the long way, even if we do it as fast as we can.

I can go one step farther and say explicitly that there is not any reason to expect that an atomic energy industry will spring into being overnight and make its appearance as a colossus upon the national scene, displacing at once the power industries which now serve us and disrupting in a few years the whole pattern of our economy. Our judgment is that no one should delay sound and economical additions to power supply, whether by fuel-generated electricity or water power, because somewhere in the future atomic energy will come on the scene as an additional source of supply.

Early American Wooden Boilers

By CYRIL G. R. HUMPHREYS

Combustion Engineering Company

WITHOUT some consideration of pre- and post-American Revolutionary War history it is hard to surmise reasons for the several wooden boilers that were built and operated in America 150 and more years ago. However, when one considers an Act of Parliament which worked to the disadvantage of Colonials, soon to become free Americans, the logic behind the wooden boilers becomes apparent. This was: "An Act to encourage the Importation of Pig and Bar Iron from His Majesty's Colonies in America; and to prevent the erection of any mill or other Engine for Slitting or Rolling of Iron; or any Plating Forge to work with a Tilt Hammer; or any Furnace for making Steel in any of the said Colonies."

After the hardships of war and the impoverishment of victory, the land needed fortitude and resourcefulness in all men. Then came the great American counterpart of England's James Watt, Oliver Evans, who contrived to make boilers of wood for lack of metal plate. His first attempts are described in a publication entitled "The Abortion of the Young Steam Engineer's Guide" (1805) from which the following is quoted:

"In the year 1801 I constructed, for the purpose of making experiments, a small boiler of cedar wood, 12 in. diameter and 20 in. in height, strongly hooped with iron. Inside of this cylinder was put a cast-iron furnace 7 in. diameter at the lower and 3 in. diameter at the upper end, with a flange 12 in. diameter at each end, which served as heads for the wooden cylinder. I fixed a safety valve and cock in the upper. The space between the furnace and the wooden cylinder contained the water which surrounded the fire. A small fire in this furnace soon raised the power of the steam to such a degree as to lift the safety valve loaded with 152 lb to the inch. I then opened the cock, regulating it so as to keep the valve just lifting. The quantity of steam which continued to escape while the fire was kept up, and the force with which it issued, was astonishing. The degree of heat which produced this immense power did not in the least injure the cedar wood. No further experiments were necessary to prove the practicability of the application of my principles."

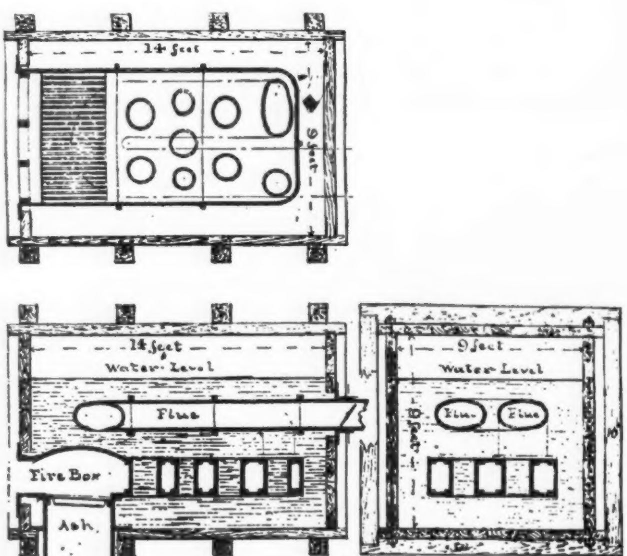

Fig. 1—F. Graff's drawing of Centre Square Waterworks boiler, reproduced through the courtesy of Franklin Institute

Jonathan Hornblower, an English contemporary of Watt, had already built engines in America, and his associate, John Nancarrow, finally came to live in Philadelphia, where he probably worked on the strange Hornblower type beam pumping engines erected there in 1801. The Centre Square engine is shown in Fig. 2. Suffice it to say that it was almost a wooden engine. The flywheel, crankshaft, connecting rod, bearings, hotwell, hot- and cold-water pumps, cold-water cistern and boiler—all were of wood.

The boiler, Fig. 1, was similar to one of Oliver Evans' later designs. A contemporary describes it (there were two similar units) in the following words:

"The boilers were rectangular chests, made of white pine planks five inches thick. They were nine feet square inside at the ends, and fourteen feet long in the clear; braced upon the sides, top, and bottom with oak scantlings ten inches square, the whole securely bolted together by one and a quarter inch rods passing through the planks. Inside of this chest was placed an iron fire-box twelve feet six inches long, six feet wide, and one foot ten inches deep, with vertical flues, six of fifteen inches diameter and two of twelve inches diameter; through these the water circulated, the fire acting around them and passing up into an oval flue situated just above the fire-box, carried from the back of the boiler to near the front, and returned again to the back, where it entered the chimney. This fire-box and flues appear to have been at first made entirely of cast-iron; this not being satisfactory on account of the unequal contraction and expansion of the two metals causing leakage, eventually wrought-iron flues were put in.

"Great advantage was at the time supposed to be gained by the nonconducting powers of the wood, and also by the vertical flues in the fire-box.

"By experiments made with the engines when the above-described wooden boiler was in use, it was recorded that the engine at Chestnut Street, on the Schuylkill, whilst lifting the water to the height of thirty-nine feet, and running at a speed of sixteen revolutions per minute, raised a total of 1,474,500 ale gallons of water in twenty-four hours, with a consumption of seventy bushels of Virginia coal. And the engine at Centre Square, raising the water fifty-one feet, pumped 962,520 ale gallons in twenty-four hours, with a consumption of fifty-five bushels of the same kind of coal; the pressure of steam, in both cases, being two and one-half pounds to the square inch."

This description and Frederic Graff's drawing, Fig. 1, indicate that the unit was in some respects a water-tube boiler. We digress briefly to point out that the wooden boiler, built so long before the modern steel giant, shown in Fig. 2 for comparison, was itself a large unit by comparison with a small bronze water-tube heating boiler dug up at Pompeii (destroyed A.D. 79).

Benjamin H. Latrobe, waterworks engineer, recorded in 1804:

"Wooden boilers have been applied in America to the purpose of distilling for many years. Mr. Anderson whose improvements in that art are well known, appears to have first introduced them in America. But it was found that the mash had a very injurious effect upon the solidity of the wood; for while the outside retained the appearance of soundness, and the inside that of a burnt, but hard surface, the body of the plank was entirely decayed. It was, however, still to be tried whether simple water and steam would have the same effect. Upon the hint of Chancellor Livingston, our present Ambassador in France, Messrs. Roosevelt, Smallman and Staudinger contrived the wooden boiler, which has been used for all the engines in New York and Philadelphia; and not without its great, though only temporary, advantages. The construction of the wooden boiler will be best understood by reference to the plan and section of the new boiler of the engine in Centre Square, Philadelphia, which is by far the best of those which have been made. It is in fact only a wooden chest containing the water, in which a furnace is contrived, of which the flues wind several times through the water, before they discharge themselves into the chimney."

An interesting reminder of an enduring effect of George II's aforementioned Act of Parliament is contained in a progress report by Thomas P. Cope, dated July 4, 1800 which stated:

"The wrought iron for the flue of the boiler over the fire will be imported from England, and is in sheets 39 by 32 inches. That yet made in this country is clumsy stuff

(*Continued on page 45*)

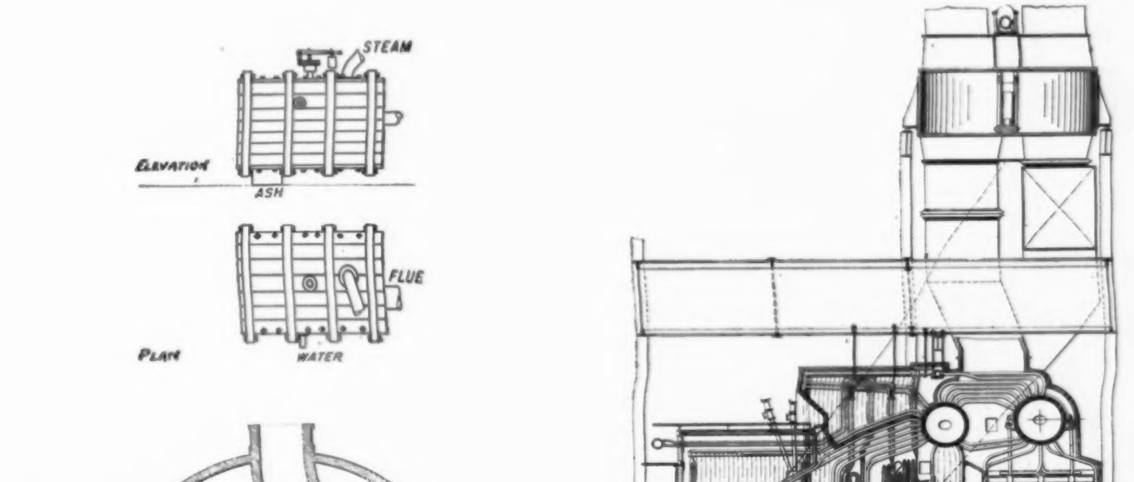

Fig. 2—Hornblower pumping engine and wooden boiler of Centre Square Waterworks, 1801 (courtesy of Franklin Institute), and operating at 2.5 psi, compared with modern million-pound-per-hour, 1600-psi steam generator of 18,000 times the energy output

An Appraisal of the Gas Turbine for Power Plants

The gas turbine has attracted much attention during the last few years and some exaggerated statements of its possibilities have been made. At the same time, engineers have studied its thermodynamic and operating cycles. Many excellent discussions of such cycles have been presented in the technical press and proposals have been advanced for applications of the several types of gas turbines to airplanes, locomotives and power generation. Executives and engineers are interested in the present state of development of gas turbines and in the availability of such units for power development in the near future. The writer has recently had an opportunity to study these new developments, both here and abroad, and the following paragraphs present his views on the situation.

By A. G. CHRISTIE

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THE cycle of a gas turbine may be considered as the series of thermodynamic changes through which the working fluid goes, from its admission into the gas turbine until its final exhaust. Cycle efficiency is the ratio of the net energy available for work to the heat energy in the fuel consumed. In some cases a secondary fluid also goes through a cycle which is supplementary to the main turbine cycle. The several possible cycles have been discussed extensively by others so that a brief outline of each need only be presented in order to clarify the turbine types considered later.

The cycle of a simple gas turbine consists of the compression of a given quantity of air at high efficiency to a specified pressure, the combustion of a quantity of fuel in this compressed air to raise the temperature of the resultant gases to a certain degree thereby increasing their volume, and the expansion of these hot gases to atmospheric pressure in an efficient gas turbine. The difference between the turbine output and the power input to the compressor is the net energy available for driving a generator or other equipment. Obviously, the greater the efficiencies of turbine and compressor, the larger will be the quantity of energy thus available for useful work.

The following general statements apply to gas turbine cycles:

(*a*) The higher the gas temperature to the turbine, the larger the net energy available for work and the greater the cycle efficiency.

(*b*) The colder the air intake to the compressor, the less is the volume of a given weight of air. As a result, less work is done in the compressor and again cycle efficiency is raised.

(*c*) The reduction of exhaust gas temperature by means of a heat-exchanger which transfers heat from exhaust gases to the compressed air before this air enters the combustion chamber, increases the cycle efficiency by burning less fuel, if pressure losses of both compressed air and exhaust gases in passing through the exchanger are small.

(*d*) Modifications of the simple cycle by intercooling the air during compression and reheating the gases during expansion of the working fluid in the turbine, increase both the unit quantity of energy available for work and the cycle efficiency.

Since gas turbines will be competitive with other forms of prime movers, these considerations will dominate cycle development within commercial limitations. Gas temperatures to the turbines are limited to about 1250 F by metals presently available. However, extensive research on metals at higher temperatures indicates that this temperature limit may be raised substantially in the near future with considerable gains in efficiency.

Low air-inlet temperatures suggest that the gas turbine is more attractive for locations in the northern sections of this country and in Canada. Also, that its capacity and efficiency will be greater in winter than in summer. Nettel has proposed a modification of the cycle whereby the intake air is undercooled by ammonia refrigeration provided by an absorption system, the heat for which is furnished by the exhaust gases of the turbine. Such a plant is a promising proposition for large gas turbine installations in our Southern states when fuel costs justify the added investment.

Heat-exchanger design requires a careful study of heat transfer between gases through metal walls with minimum pressure drops on both fluids. This problem is receiving study and improvements can be expected in the design of heat-exchangers.

Finally, the gains from intercooling and reheating have led to multi-cylinder designs in large units. Such two-shaft designs also possess some distinct advantages in governing and in higher part-load efficiencies than single-shaft units.

Cycles Now in Use

Three general types of cycles are in use. In the open cycle, fresh air is taken into the compressor, raised to the necessary pressure, heated in the fuel combustor, expanded in the turbine and exhausted to atmosphere with or without a heat-exchanger. No cooling is required other than for bearing oil unless intercoolers are added. Even in this case the quantity of heat to be removed is not large. Open-cycle gas turbines therefore seem more suitable for such services as locomotives, or for locations where water is scarce or costly, as, for instance, in central sections of a city not close to a supply of water or in the dry sections of the West.

In the closed cycle the working fluid is continuously circulated. After compression, the working fluid is heated in closed tubes like boiler tubes and out of contact with the combustible gases. It then expands through the turbine and exhausts into a heat-exchanger and then into a cooler which reduces it to initial temperature before re-entering the compressor. The advantage claimed for this system is that the working fluid can operate at higher ranges of pressure than in the open cycle with a resultant reduction in the size of compressor and turbine. Also, any type of fuel can be used to supply heat without contaminating the working fluid. It is proposed to use a neutral working fluid such as carbon dioxide or helium which would have no oxidizing effect on any hot parts. This system is said to require about half the amount of water for cooling purposes that would be needed by a steam condensing plant of the same kilowatt output. Hence a supply of cooling water must be available at its site.

A semi-closed cycle has been developed where a portion of the working fluid—in this case, air and combustion gases—passes through on an open cycle while the remainder operates on a closed cycle. Pressure ranges are intermediate between the open and closed cycles. Since only that part of the working fluid which operates on the closed cycle needs to be pre-cooled before compression, the cooling water requirements are less than in the closed cycle but greater than in the open cycle.

Each cycle has its good points. First costs and operating experience must be determined to properly evaluate these cycles for commercial use.

Efficiencies

Efficiency depends upon the four factors noted previously. Turbine builders, as a rule, do not care at present to exceed 1250 F gas temperature. With this temperature and with intercoolers, reheaters and a large exhaust heat-exchanger, the guarantees on larger units represent efficiencies of about 29 to 31 per cent at full load, depending on inlet air temperatures. This efficiency is based on the high heat value of the fuel. Statements on foreign units may show higher values of efficiency but these foreign figures refer to the low heat value of the fuels supplied. Therefore, reduction of 8 to 10 per cent must be applied to these foreign figures to compare them with American performance values with liquid or gaseous fuels. Naturally the efficiency of units without intercooolers, reheaters and heat-interchangers will be lower. Also, lower initial gas temperatures to the turbine lead to greatly reduced efficiencies.

Few data are available on the efficienices at partial loads. These depend to a large extent on the characteristics of both compressor and turbine and largely on the plant design and system of governing. Where two-stage expansion is employed on two-shaft machines, with or without reheating, it is frequently found advisable to drive all the compressors by one turbine which can then run at variable speed, depending on load. The second turbine drives the electrical generator at constant speed. This two-shaft arrangement is said to provide higher efficiency at partial loads than could be obtained with constant speed on both shafts.

A majority of gas turbines have been provided with axial compressors which have been developed to a high degree of efficiency. However, the characteristics of this type are such that efficiency falls off rather rapidly below best load. Improved forms of compressors with radial blades and correctly designed diffusers are under development which are said to give as high efficiency at best load as can be obtained on axial compressors and with better efficiencies at partial loads. Undoubtedly the good features of both types will be incorporated in future units, probably as a combined axial-radial design.

Attention is drawn to the efficiencies stated above of 29 to 31 per cent. These are substantially the efficiencies of many of our best steam-turbine stations at the present time. Hence the gas turbine at its present stage of development should give the same efficient performance as the best steam central station, although the gas-turbine units are relatively small as compared to the large steam turbines in the best central stations. Further developments in gas turbines may be expected to provide units of higher efficiencies than can now be achieved in these steam stations.

Comparison with Diesels

How does the gas turbine compare with diesel engines? In the first place, the largest diesel engine to the writer's knowledge was reported as of about 15,000 kw while gas turbines are under construction much larger than this capacity. Hence the larger gas turbines will be more applicable to central station service than diesel engines. In the sizes comparable to those of current diesel engines many believe that the rotary gas turbine will have constructional, operating and maintenance advantages over diesel engines. The efficiencies expected of present gas turbines compare favorably with those of diesel engines when measured at the generator terminals. As noted above developments in gas turbines should improve efficiencies.

Fuels

Natural or other gases if reasonably clean, make ideal fuels for gas turbines. Extended experience with gas turbines in connection with Houdry oil refining units indicates that small amounts of dust in the gases cause no serious difficulties.

Most of the foreign gas turbines operate with fuel oil. This has generally been one of the several grades of commercial fuel oil. When heavy oil of Bunker C grade has been used, blade deposits have been experienced with certain Middle East and South American oils. These probably correspond to slag deposits on steam boiler surfaces when similar oils are burned.

Many attempts are being made to adapt the gas turbine to coal. The closed cycle of Escher Wyss & Co., Zurich, Switzerland, is designed so that pulverized coal may be burned. Another foreign builder is endeavoring to develop a pressure gas producer that can be operated in conjunction with the gas turbine. Other organizations are endeavoring to burn pulverized coal directly in an open-cycle type of unit. The efforts of the Locomotive Development Committee of Bituminous Coal Research to develop a pulverized-coal-fired gas-turbine locomotive have resulted in a satisfactory process and two locomotives of 3500 hp are on order for delivery in 1948. Developments to date indicate that the gas turbine can be built for coal firing.

Plant Design

The Parsons type of turbine has been preferred for the majority of large gas turbines as it can develop high efficiency at moderate wheel speeds. Impulse turbines are also being developed. The principal problem is to provide blading which will withstand high gas temperatures. Air cooling of the first rotor blades was employed on some German designs and may be used if gas temperatures are increased above present figures. Another possibility is the provision of an impulse first stage on Parsons turbines to provide for a large temperature drop. Refractories may also be used to coat first-stage blades or to serve as blading materials.

A gas-turbine plant is comparatively simple. There is only the turbine room with a relatively low basement for piping. The total height from basement floor to roof need not be as high as modern steam-turbine rooms. Heat-exchangers can be placed outside as there are no parts to freeze in cold weather. Hence total floor space requirements are not large. The auxiliaries are few and consist of starting equipment, fuel oil pumps and lubricating oil plants. Operation should require little labor.

High velocity in the intake to the air compressor may cause a shrill noise that would be objectionable in many locations. Means must be developed to deaden this sound particularly with large units.

Gas-turbine plants which need little water have a remarkable versatility of location. They may be located at inland load centers where there is insufficient water for a steam-turbine plant. Also, where oil or gas fuel is used, they may be placed in residential sections since no smoke or dust nuisance would be experienced.

Current Gas Turbine Developments Abroad and in The United States

Much development work on gas turbines was carried out abroad during the war, principally by Swiss builders.

Brown Boveri & Cie, Baden, Switzerland, have built units of 10,000 and 12,000 kw and are now building for the Swiss government a 27,500-kw set for operation in winter when there is a deficiency of hydro power. This firm has also built gas-turbine locomotives. Preference is given to gas inlet temperatures to the turbine of about 1100 F. Brown Boveri has built more commercial units than any other European firm, all of which are of the open-cycle type.

Escher Wyss Machine Works, Zurich, Switzerland, has had an experimental 2000-kw closed-cycle unit in operation for several years with working pressures up to 850 psig. A 13,000-kw unit has been sold and is now under design on this cycle in addition to two for Italy. Fuel will be burned in a supercharged furnace where furnace temperature is controlled by the recirculation of flue gases. Since the working fluid must be cooled, this unit will require a supply of circulating water.

Gebruder Sulzer, Winterthur, Switzerland, has carried on development of a semi-closed cycle and has sold a 20,000-kw unit of this type. Heat transfer takes place between gases that are under considerable pressure and hence the heat-exchanger parts and piping are relatively small. Gas temperatures of 1200 F will be maintained at the turbine throttles. This unit will require cooling water for a portion of the working fluid.

Ateliers de Construction Oerlikon, Oerlikon, Switzerland, is developing a gas turbine with a radial air compressor having a specially designed diffuser for which claims are made of high compressor efficiency especially at light loads. An experimental unit has been operated for some time. The firm is prepared to accept orders for large units.

C. A. Parsons & Co., Newcastle, England, has had an experimental gas turbine in operation for several years and has accumulated extended performance data with various fuels. This is a standard open-cycle unit. The firm will consider proposals on 10,000- to 30,000-kw units.

Metropolitan-Vickers Electrical Company has furnished a 2500-hp gas turbine for a British naval vessel. This has undergone extensive trials which were recently reported in the British press. This concern is said to be prepared to furnish larger units.

Other British firms such as British Thompson-Houston Co.; Frazer & Chalmers; Richardson, Westgarth & Co., and others are said to be designing gas turbines of larger sizes but are not prepared to state details at this time.

The British Government is said to have placed several orders for gas turbines up to 15,000 kw unit capacities with several builders.

Allis-Chalmers Mfg. Co., Milwaukee, Wis., has furnished over twenty-five gas turbines for Houdry oil refineries. These have a comparatively small output. Proposals have been offered on units of 10,000 kw capacity to operate on the open cycle.

.Elliott Co., Jeannette, Pa., has developed an open-cycle unit of about 3500 hp.

General Electric Co. recently released a description of a 4800-hp locomotive unit[1] and has announced that it is prepared to offer power units up to approximately 6000 kw capacity.

Westinghouse Electric Co. has developed an open-cycle locomotive unit but, in so far as the writer is aware, has not offered any large units for power generation in stationary plants.

De Laval Steam Turbine Co. and Northrup-Hendy Co. are working on gas turbine developments but have not entered the commercial field, nor have they publicized their types.

Little can be said at this time regarding first cost of gas turbines. Quotations on foreign built units would indicate somewhat lower overall costs than for American steam-turbine plants. Prices of American gas turbines appear somewhat high due to the probable inclusion of

[1] *Power*, August 1947.

large development expense and the use of special alloys whose fabrication is not yet standardized.

Another consideration in the purchase of gas turbines is the availability and cost of an adequate supply of fuel oil when this is used. Present trends indicate that increased prices may be expcted for this fuel.

Availability and Reliability

Plant owners and engineers are interested not only in the economics of the gas turbine but also in the degree of availability and reliability of such units.

The gas turbines used in the Houdry process plants have, according to Pew[2], given excellent performances fully as satisfactory as steam-turbine stations. However these have operated at temperatures at or slightly above recent steam-turbine practice.

The 3500-hp experimental Allis-Chalmers unit at Annapolis, Md., has operated satisfactorily at temperatures above those presently contemplated.

No data are available on the larger units that have been built abroad and referred to previously.

On the record, therefore, there are comparatively few data upon which to base an appraisal of the availability of large gas turbines. Yet the same was true of large steam turbines when the late Samuel Insull ordered the then "large" 25,000-kw steam turbine for Fisk Station, Chicago, about 1911. C. A. Parsons & Co. had built no unit approximating this size although it had furnished many smaller ones. As is well known, this Parsons unit gave such excellent satisfaction in operation that it became known as "Old Reliable."

Builders of gas turbines now understand the underlying principles of design and of high temperatures in metallurgy. Better materials are available now than in 1911. Confidence can be placed in the ability of the designing engineers of the different builders to develop satisfactory large gas turbines. Manufacturers are swamped with orders for all lines of product so that deliveries within three to four years are about the best to be expected, should orders be placed for large gas turbines.

Based on extended acquaintance with gas-turbine development, it is the writer's opinion that developments in gas turbines have reached the point where economical and reliable units can be furnished. The designs of these units will be prepared by competent engineers and the firms which will build these units are dependable and able to construct satisfactory gas turbines. Theoretical and practical problems are well understood and are given careful consideration in designs. Confidence in the success of such turbines is therefore justified.

[2] "Operating Report on Gas Turbine Use in Sun Oil Refineries," by A. E. Pew, Jr., *Mechanical Engineering*, Sept. 9, 1945.

(*Continued from page 39*)

of different sizes, the largest being 36 by 18 inches, with rough edges which have to be cut smooth by the purchaser."

The foregoing comments and notes would have been less interesting to us if the boilers had been used for services of a more ordinary nature, but with all their wooden frailties, these units were signally honored to supply steam to intricate prime movers in a public utility of high importance, to wit, a city's waterworks. Evidently they operated satisfactorily for the Centre Square unit continued for fourteen years until the whole waterworks was superseded in 1815.

Before emerging from this engine-room of bygone days it may be of interest to draw a comparison between the obscure wooden antiques and a large modern steam electric plant.

The Centre Square unit consisted of a wooden boiler serving a steam pump with $2^1/_2$ psi saturated steam. This pump performed 412,000,000 ft-lb of work each day for a consumption of 5500 lb of coal. This is equivalent to 0.04 hp-hr per pound of coal.

The modern steam-generating unit shown in section at the right in Fig. 2 is rated at one million pounds of steam per hour at 1600 psi and 950 F steam temperature and, with its turbine-generator, produces the equivalent of around 1.75 hp-hr per pound of coal. Thus the modern unit produces over forty times the amount of power per pound of coal as did the Centre Square unit.

For an even more striking comparison, the modern boiler burns 87,000 lb of coal when producing 1,000,000 lb of steam and 152,000 hp-hr. Similarly, when burning its maximum of 229 lb coal per hour, the old pumping engine produced 8.4 hp-hr. So the large unit produces 18,000 times as much useful energy as the old Centre Square pumping plant.

A note of tragedy. The wooden boilers were not all successful as was this one. Oliver Evans records two major wooden boiler explosions with three fatalities.

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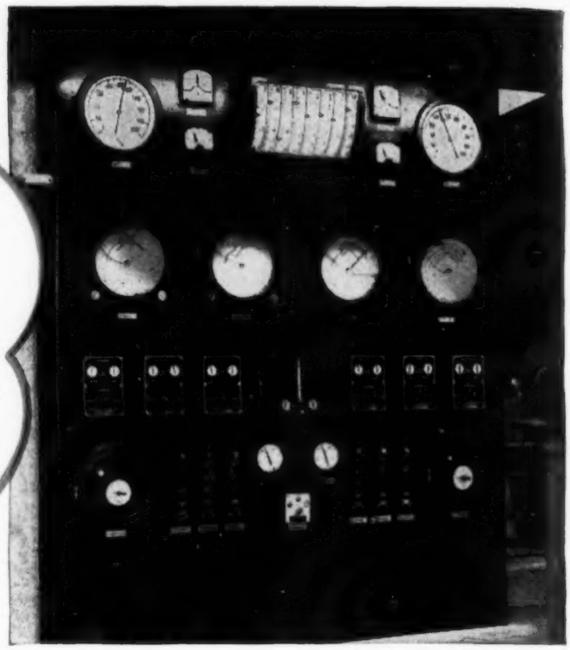
Accustomed to associating large power stations with electric utilities in this country, we are sometimes inclined to overlook what is going on in some of the more remote sections of the globe. In this connection, some readers may be surprised at the above view showing twelve 33,000-kw turbine-generators installed in the Klip Station of the Electricity Supply Commission in the Transvaal, South Africa. The aggregate of installed capacity in the several power stations owned by the commission is approximately a million kilowatts.

TIPS ON HOW TO SELECT BOILER CONTROL



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Burning Brown Coal on Stokers

In one of the papers presented at the recent Fuel Economy Conference at the Hague, the authors, Messrs. Stewart, Nicholson and Reinbach of the Australian National Committee, told how $3^1/_2$ million tons of raw brown coal with up to 66 per cent moisture, as produced in the State of Victoria, is burned annually at a mine-mouth plant for power generation and large additional tonnage is consumed in industry on spreader, underfeed and chain-grate stokers, the last mentioned provided with a pre-ignition grate. Experience with these stokers is given.

THE State of Victoria possesses vast resources of brown coal and secures the bulk of its requirements of electricity from a power station associated with a large, highly mechanized open cut, from which is obtained approximately five million tons of brown coal of 66 per cent moisture yearly. Of this, $3^1/_2$ million tons are burned at the mine for power generation and the balance is briquetted for use in other power stations and for sale to industrial and domestic consumers. However, in addition, 1,750,000 tons of bituminous coal is consumed yearly, of which $1^1/_2$ million tons are imported from New South Wales.

During the war shipping difficulties caused acute shortages of bituminous coal in Victoria and this led to extended use of brown coal by industrial plants, some of this coming from new areas of drier coal where the moisture content ranged only from 49 to 59 per cent. Since most of these existing industrial stokers had been designed for burning bituminous coal, considerable experimental work became necessary in order to adapt them to burning brown coal.

Typical analysis of this coal was 49.5 to 59.5 per cent moisture; 25.8 to 23.9 per cent volatile; 22.7 to 23.9 sulphur (dry basis); and 11,680 to 11,820 Btu per lb calorific value on a dry, ash-free basis, or 5660 Btu on a wet, as-received, basis.

Spreader Stokers

A number of spreader stoker installations were changed to brown coal with complete satisfaction. Because of the overfeed nature of firing, no difficulties were experienced with ignition, but initially it was feared that high cinder losses might occur because of the low specific weight of the coke from brown coal. Few of the installations had cinder arrestors and the stokers with manual dumping grates were not fitted with automatic control other than "on-and-off" switches. Despite these disadvantages, good outputs were obtained and there was remarkable freedom from fly ash or cinder stack discharge, due probably to the low ash content and to the very high reactivity of the brown coal.

Underfeed Stokers

The bituminous coal available during the last few years has run high in fines with an ash content of 16 per cent or higher and ash-fusion temperatures ranging from 2400 F upwards. Hence the tendency has been toward thin fires and high excess air in an attempt to avoid clinkers and smoke. It was found that by mixing bituminous and brown coal in approximately equal volumes that more uniform combustion could be obtained and lower excess air carried without clinker difficulties and with improved boiler efficiency.

Early experiments with brown coal alone on underfeed stokers did not appear promising, but it was later found that as long as thick fuel beds were carried a suitable fire could be maintained with brown coal alone. However, the volume of brown coal required is very much greater than that of bituminous coal because of the high moisture, and this increased volume necessitated larger screws or higher speeds.

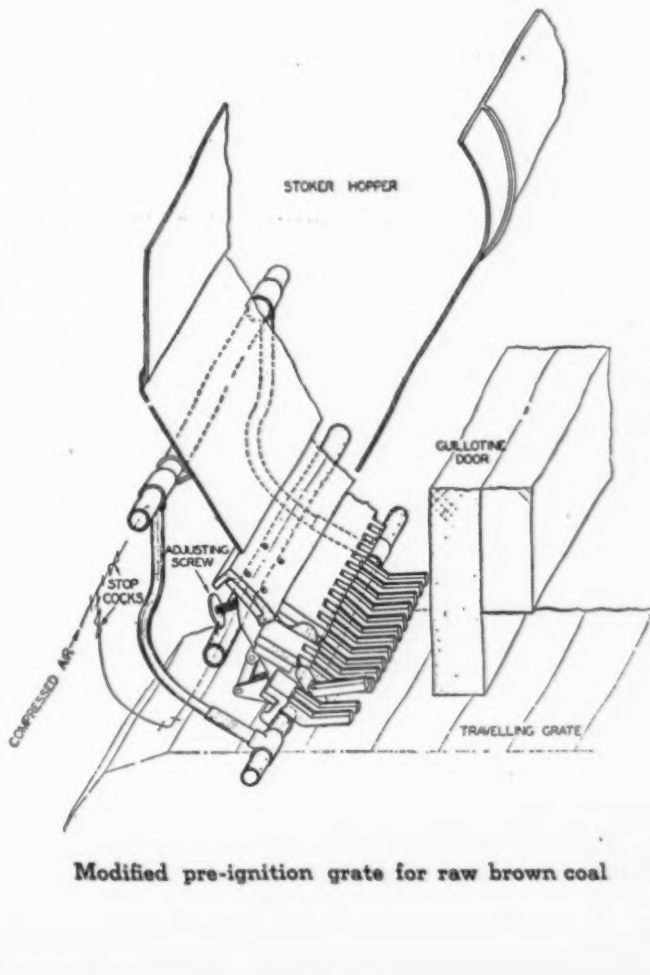
Because of its low ash content a brown coal fire does not require as much labor in cleaning fires as does bituminous coal, but occasional attention is necessary to remove clinkers from around tuyères or from the slopes of the grate. It is also sometimes necessary to level the fire from front to back.

Furthermore, sizing is rather critical and, in order to avoid packing difficulties, the percentage of fines on a $^1/_8$-in. screen should not exceed 10 per cent. The upper size is not critical, and 4-in. lumps pass satisfactorily through 6-in. screws. Overall net thermal efficiencies up to 70 per cent were obtained when burning brown coal of 48 per cent moisture.

Chain-Grate Stokers

Most medium and large industrial boilers in Victoria have chain grates. Since the basic principle of chain-grate ignition is not suitable for high-moisture fuel, a departure from normal practice was unavoidable. Mixtures of bituminous and brown coals, up to 60 per cent of the latter by volume, were burned successfully and normal rating could be obtained at

(Continued on page 48)



Modified pre-ignition grate for raw brown coal

satisfactory efficiency; but adequate mixing is difficult.

Auxiliary oil ignition has been widely used when burning brown coal on chain grates, the oil burners being set in the side walls below the front arch and about 15 in. above the grate. Auxiliary spreading, by blowing the fines through the front or side walls, was also tried.

However, since none of these methods appeared desirable for general application, a pre-ignition grate was developed. This was based on the earlier German ideas for burning brown coal briquettes. As indicated in the sketch, it comprises a short step-grate mounted at the stoker hopper immediately before the traveling grate. Some fuel is retained on the steps of the pre-ignition grate where it dries and burns. From this ignited fuel a trickle of burning particles falls through the prongs onto the chain grate and these are carried into the furnace beneath the main body of fuel; under the influence of the furnace draft, ignition spreads upward rapidly through the fuel bed. Because of the original impossibility of ignition of the high-moisture coal with normal equipment, it was decided to stimulate burning on the steps of the pre-ignition grate by fitting a series of small air jets in front to impinge on the coal retained on the prongs. This made satisfactory operation possible.

Fuel Exports

The First Quarterly Report to the President and Congress by Secretary of Commerce Harriman, as called for under the Second Decontrol Act of 1947, has just been issued and, among other things, gives the facts on current exports of coal and oil, concerning which many varying reports have been circulated from time to time.

Coal production in the United States this year is estimated at 600 million net tons which is nearly 50 per cent greater than that of 1939, but output by the rest of the world is about 540 million tons below the prewar figure.

During the third quarter of 1947, despite a heavy domestic demand, the output was sufficient to warrant export shipments of 23 million tons, including 9 million tons to Canada, bringing the total for the year through September to about 54 million tons. The shipments were all under export license.

Petroleum

Shortly after V-J Day export control was removed from most petroleum products, although heating fuels were kept under control during the following winter and were removed late in 1946.

In recent months there has been a marked demand in domestic consumption of gasoline, fuel oil and other petroleum products with the result that the demand has reached an all-time high, exceeding even the wartime peak.

Spurred by this increased demand, output of petroleum in the United States has increased, but not at a rate commensurate with the increased requirements; and it has become necessary to rely upon imports

to help out the deficiency. But transportation limitations are being encountered and, as a result, spot shortages have occurred in various localities and military requirements are not being fully met. Therefore, in order to protect the limited domestic supply and to permit exports to be used most effectively in the interests of world recovery, stringent export controls were reimposed during the third quarter of 1947 on gasoline, kerosene, fuel oil and certain other petroleum products.

Approximately one-fourth of our exports of liquid petroleum products during the first eight months of the present year went to Canada and other countries in the Western Hemisphere. The remaining three-fourths, to various other countries, was at an annual rate of 66 million barrels, or less than 4 per cent of the total domestic supply. By comparison, petroleum exports in 1939 amounted to 87 million barrels or 7 per cent of our supply (this included the high Japanese demands at that time).

It is of interest to observe that the total exports of petroleum products to Russia during the first eight months of 1947 amounted to approximately a million barrels, whereas for the year 1946 they amounted to about $2\frac{1}{2}$ million barrels. In other words, the first eight months' exports this year to Russia were only about $1\frac{1}{4}$ per cent of our total export of petroleum products during this period.

A Consistent User of Reheat

The article on reheat in the September 1947 issue of COMBUSTION is most intriguing but hardly accurate, as far as the American Gas and Electric system is concerned.

As is well stated in the body of the text, the employment of the reheat cycle in the United States dates back to the middle 20's. At that time three 600-psi, 725 F, reheat plants were laid down on the American Gas and Electric Company system: Philo units 1 and 2 with a total capacity of 80,000 kw; Twin Branch units 1 and 2 with a total capacity of 80,000 kw; and Stanton units 1 and 2 with a capacity of 100,000 kw. These were followed, however, by Philo No. 3 in 1930 with a capacity of 165,000 kw, by Deepwater in 1930 with a capacity of 106,000 kw, and by Twin Branch No. 3 in 1941 with a capacity of 76,500 kw. The list is now being expanded by Twin Branch No. 5 and Philip Sporn Nos. 1 and 2, each with a capacity of approximately 150,000 kw, a total of 450,000 kw. Steam conditions are 2000 psi, 1050 F, with reheat to 1000 F. The total capacity represented by this series is well over 1,000,000 kw.

The answer, therefore, to the question "Is Reheat Coming Back?" is that on the American Gas and Electric system it never left home. It is gratifying, however, to find that engineers and executives in the power industry, in general, are coming to recognize the advantages that can accrue from the use of reheat when obtained under properly designed conditions.

PHILIP SPORN, Pres.
American Gas & Electric Co.

CEC Sales Changes

Several shifts in sales personnel have been announced by Combustion Engineering Company, Inc. **G. P. Ellis,** for several years District Manager of the Cincinnati Office, has been transferred to California. His place in Cincinnati is being taken over by **H. H. Michelsen** who had been Manager of the Rochester Office. In turn, Mr. Michelsen's place in Rochester is being taken over by **R. F. Broas,** formerly assistant to the General Sales Manager in New York.

Other changes are **W. J. Woodruff** to the St. Louis Sales Office; **Ray Page** from Chicago to St. Louis Maintenance Sales; **J. K. Harvey** from the New York Proposition Department to the Chicago District Office; **Herman Reichard** to Chicago Sales; and **John Sinica** from the Proposition Department, New York, to the Pittsburgh Office on Maintenance Sales.

Iron and Steel Scrap Shortage

If American steel mills are to maintain the production rate required by domestic and foreign commitments, they must be supplied with larger quantities of iron and steel scrap, according to Secretary of the Interior, J. A. Krug. Investigations conducted by the Department of the Interior at the President's request in connection with the proposed Marshall Plan have underscored the critically short supply of these materials which are urgently needed in steel production.

A.S.M.E. ANNUAL MEETING PROGRAM BRIEFED

DIGRESSING from the customary practice of holding the Annual Meeting of the American Society of Mechanical Engineers in New York City, it will this year be held at Atlantic City, N. J., December 1 to 5, with headquarters at the Chalfonte-Haddon Hall Hotels.

There will be 74 technical sessions with more than 200 papers. Inasmuch as the meeting will extend over five days, evening sessions, with one or two exceptions, will be avoided. In addition to the technical sessions, there will be addresses by a number of prominent individuals including David Lilienthal, chairman of the Atomic Energy Commission; F. S. McConnell, president of the National Coal Association, and Alvin E. Dodd, president of the American Management Association.

At the banquet on Wednesday evening, at which President O'Brien will be the speaker, honorary membership will be conferred upon Harvey N. Davis, president of Stevens Institute of Technology, Francis Hodgkinson, consulting engineer, Everett G. Ackart of Wilmington, Del., and Hon. George C. Marshall, Secretary of State. The usual medals will also be awarded at this time.

There will also be an educational exhibit of equipment and material reflecting engineering and scientific developments in the fields of jet propulsion, gas turbines and nuclear energy.

The technical program covers ten sessions on Applied Mechanics, nine on Heat Transfer, five on Railroads, seven on Management, five on Fuels, seven on Gas Turbines, four on Power, four on Aviation, three on Properties of Gases, two each on Petroleum, Industrial Instruments, Lubrication, Rubber, Plastics and Wood Industries, and one each on Hydraulics, Process Industries, Fluid Meters and Safety. There will also be several joint sessions with the American Rocket Society. Only those papers that have identification with the power plant field will be here listed as follows:

Monday, 9:30 a.m.

"Flash Drying," by C. W. Gordon, Raymond Pulverizer Division, Combustion Engineering Co., Inc.

"Heat Transfer Through Thick Insulation on Cylindrical Enclosures," by G. M. Dusinberre, Univ. of Delaware, and T. S. Nickerson, E. I. du Pont de Nemours & Co.

Monday, 2:30 p.m.

"Continuous Determination of Oxygen Concentration Based on the Magnetic Properties of Gases," by R. D. Richardson, The Hays Corp.

Tuesday, 9:30 a.m.

"Notes on Tightness of Expanded Tube Joints," by George Sachs, Case Institute of Technology.

Panel Discussion on Heat Exchangers

"Problems Associated With the Use of Diesel Fuel Oil," by W. L. H. Doyle and E. W. Landen.

"Removal of Aldehydes From Diesel Exhaust Gas," by Rogers F. Davis and M. A. Elliott, U. S. Bureau of Mines.

"An Experimental Determination of Sound in Superheated Steam by Ultrasonics," by James Woodburn, Johns Hopkins Univ.

Tuesday, 12:15 noon

Nuclear Energy Luncheon—"Atomic Energy and the Engineer," by David Lilienthal.

Tuesday 2:30 p.m.

"Locomotive Firebox and Boiler Performance," by F. D. Mosher, Standard Stoker Co.

"Nuclear Energy—the Basic Design Background," by John R. Huffman, Clinton Laboratories, Oak Ridge, Tenn.

"High-Performance Surfaces for Gas-Turbine Plant Regenerators," by A. L. London, Stanford Univ., and C. K. Ferguson, Univ. of California.

"A Design Method for Counterflow Shell-and-Tube Heat Exchangers for Gas Turbines," by D. G. Shepherd, Malton, Canada.

Panel Discussion on Heat Exchangers, led by K. A. Gardner, The Griscom-Russell Co.

Tuesday, 6:30 p.m.

Fuels Dinner with president-elect, E. G. Bailey, toastmaster, and Fred S. McConnell, the speaker, whose subject will be "The Coal Industry Looks Ahead."

Wednesday, 9:30 a.m.

"Ignition of Flame Stabilization Processes in Gases," by Bernard Lewis and Guenther von Elbe, U. S. Bureau of Mines.

"Prediction of Pressure Drop During Forced-Circulation Boiling of Water," by R. C. Martinelli and D. B. Nelson, General Electric Co.

"The 2000-psi, 1050-F and 1000-F Reheat Cycle at the Philip Sporn and Twin Branch Steam-Electric Stations," by Philip Sporn, president, American Gas & Electric Service Corp.

Wednesday, 2:00 p.m.

"Gas-Turbine Plant Combustion Chamber Efficiency," by Prof. A. L. London, Stanford Univ.

"Temperature Measurements and Combustion Efficiency in Combustors for Gas-Turbine Engines," by W. T. Olson and Everett Bernardo.

"Determination of Gas Turbine Combustion Chamber Efficiency by Chemical Means," by Peter Lloyd.

Wednesday, 6:30 p.m.

Banquet with President E. W. O'Brien, speaker, whose subject will be "Accents on Youth."

Thursday, 9:30 a.m.

"Axial Flow Compressors for Gas Turbines," by A. I. Ponomareff, Westinghouse Electric Corp.

"Furnaces for By-Product Fuels," by Otto de Lorenzi, Combustion Engineering Co., Inc.

"Experimental Combustion of Pulverized Coal at Atmospheric and Elevated Pressures," by H. R. Hazard, Battelle Memorial Institute, and F. D. Buckley, Locomotive Development Committee.

Thursday, 2:00 p.m.

"Why Pollution Abatement Concerns the Mechanical Engineer," by J. R. Hoffert, Health Dept., Commonwealth of Pennsylvania.

Symposium on "Heat Values of Fuels for Thermal Efficiency and Power Cycle Analysis," including: "Current Definitions of High- and Low-Heat Values of a Fuel and Current Methods for Their Determination," by E. F. Fiock, National Bureau of Standards; "Current Definitions of Thermal Efficiencies and Current Usage of Observed Fuel Heat Values and Consumption Test Data," by Prof. A. G. Christie, Johns Hopkins Univ.

"Mechanisms of Combustion and Their Relation to Oil Burner Design," by Harold R. Heiple and William A. Sullivan, Shell Oil Co.

"Synthetic Liquid Fuels in the United States," by W. C. Schroeder, U. S. Bureau of Mines.

Thursday, 8:15 p.m.

"Technical and Economic Aspects of Water Purification," by R. V. Kleinschmidt.

"Low-Pressure Steam-Heated Distilling Plants," by R. M. Bent, Griscom-Russell Co.

"Oil Elimination from Feedwater," by M. Bradt, Skinner Engine Co.

"Demineralization Processes," by D. J. Saunders, Permutit Co.

"Generalized Thermodynamics of High-Temperature Combustion," by H. C. Hottel, G. C. Williams and C. N. Satterfield, Massachusetts Institute of Technology.

Friday, 9:30 a.m.

"Lubricant Tests and Their Application to Engineering," by D. A. Hall and W. T. Everitt, Eastman Kodak Co.

"Oil Flows and Temperature Relations in Lightly Loaded Journal Bearings," by John Boyd and B. P. Robertson, Westinghouse Research Laboratories.

"Measurements of the Combined Frictional and Thermal Behavior in Journal Bearing Lubrication," by S. A. McKee, H. S. White and J. F. Swindells, National Bureau of Standards.

Friday, 2:30 p.m

"Recommended Practices for the Preparation of New Turbine-Lubricating Systems," by F. E. Rosenstiehl, The Texas Co.

"High-Temperature Performance of Silicone Fluids in Journal Bearings," by J. E. Brophy, J. Larson and R. O. Militz.

"The Hydrosphere—A New Hydrodynamic Bearing," by M. C. Shaw and Charles D. Strang, Jr., Massachusetts Institute of Technology.

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